Southwestern Bell Telephone

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"The One to Call On"

April 21, 1998

APR 22 1998

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J. A. Hearst
Director-
Planning &
Engineering
Regulatory
Support

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
1919 M St. NW, Room 222
Washington, DC 20554

Subject: Ex Parte Presentation - Voice Bandwidth To Be Used In Providing Universal Service, CC Docket 96-45

Dear Ms. Salas:

On April 20th, 1998, Southwestern Bell met with Abdel Eqab, Jane Whang, Kaylene Shannan, Natalie Wales, Thomas David, Steve Burrett, Bob Loube, Mark Nadel, and Linda Armstrong of the Universal Service Branch of the Common Carrier Bureau in regards to the staff's examination of the proposed changes to the range of Bandwidth used for the transmission voice over the switched telephone network. SBC was represented by Jimmy Salinas, Dr. Sc., James A. Hearst, of SWBT, and Ricardo J. Perez of Belcore.

There were two purposes to this meeting. The first was to provide a description of the public switched telephone network. The second was to correct several misconceptions concerning the transmission of analog data over the voice grade telephone network.

This meeting provided the commission staff with an over view of the expected performance of modems and their data over the public switched telephone network as well as an opportunity for the staff to ask questions of one of the Regional Bell Companies.

Two copies of this notice are being submitted to the Secretary of the FCC in accordance with 1.1206(a)(2) of the Commission's rules.

Attachments

cc: Abdel Eqab
Jane Whang
Kaylene Shannan
Natalie Wales
Thomas David
Steve Burrett
Bob Loube
Mark Nadel
Linda Armstrong

6500 West Loop South
Zone 1.3
Bellaire, Texas 77401

Phone (713) 567-4680
Fax (713) 567-7622

No. of Copies rec'd 0
List ABCDE

Bellcore

Bell Communications Research

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To Jimmy Salinas
6500 W Loop S
Zone 3.4
[illegible]

ANALYSIS REPORT
AR-2269
ISSUE 1, SEPTEMBER 1996

Interoperability Analysis of the Effects of Multiple Switching and DLC Systems with 28.8 kb/s Modems

Prepared by:
Integrated Access Systems, Bellcore

For further information, please contact:
Frank Tuhy
Project Director, Access Systems Analysis
445 South Street, Room MCC-1C165G
Morristown, NJ 07960
Tel: (201) 829-4967
FAX: (201) 829-5965

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TECHNICAL ANALYSIS REPORT
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ANALYSIS SCOPE NOTICE
LIST OF POSSIBLE TECHNICAL ANALYSIS TOPICS FOR DIGITAL LOOP CARRIER SYSTEMS

Bellcore has reviewed the Product Class for the Digital Loop Carrier Systems involved in this Report, and has identified the following list of topics that, in Bellcore's view, would be required for a complete analysis. Please note that this Technical Analysis Report may not include all these topics. Rather, it includes only the topic(s) checked below. These topics are grouped into four main criteria areas.

☑ **Features, Functions, and Performance** (see items on page vi)

☐ **Environmental Compatibility**

☐ **Product Reliability**

☐ **Quality Technology**

Bellcore has reviewed the Product Class for Digital Loop Carrier Systems and has identified the following lists of topics that, in Bellcore's view, a **Features, Functions, and Performance** analysis of this product would require. Please note that this Technical Audit Report does not include all of these topics. Rather, it includes only the topics checked below.

- ☑ System Configurations
  - ☑ TR-57 UDLC
  - ☐ TR-303 IDLC
  - ☑ TR-08 IDLC
  - ☐ TR-909 FITL
  - ☐ D4 INA
  - ☐ Other
- ☐ Basic System
  - ☐ Call processing
  - ☐ Traffic sensitivity
  - ☐ Fault detection
  - ☐ Failure recovery
  - ☐ Redundancy
  - ☐ Protection switching
  - ☐ Channel reassignment
  - ☐ Other
- ☐ High Speed Transport
  - ☐ SONET
  - ☐ DS-1
  - ☐ T1
  - ☐ Other
- ☑ Transmission and Signaling*
  - ☑ POTS
  - ☐ Coin
  - ☑ UVG
  - ☐ DID
  - ☐ P-phone
  - ☐ BRA ISDN
  - ☐ DDS
  - ☐ 2-wire provisionable
  - ☐ 4-wire provisionable
  - ☐ 6/8-wire provisionable
  - ☐ DS-1/T1 extensions
  - ☐ Other
- ☐ Operations Interfaces
  - ☐ Supervisory system
  - ☐ Craft interface
  - ☐ Alarm interface
  - ☐ MLT/PGTC interface
  - ☐ OS/NE interface
  - ☐ Other
- ☐ Limited Environmental Tests
  - ☐ Temperature extremes
  - ☐ Limited Level I lightning
  - ☐ Limited Level I ac
  - ☐ Limited Level II ac

* limited to 28.8 kbs Modem Performance

1. Executive Summary

1.1 Introduction

In the current business climate, where 28.8 kb/s modems are rapidly becoming the most popular means of data transfer over phone lines, customers expect a connect rate at or close to the 28.8 kb/s level. Often, however, this is not attainable, and, especially if the connect rate is severely degraded, complaints and dissatisfaction may result. Previous Bellcore analysis reports (ARs) investigated some digital loop carrier (DLC) system[1] and line unit (LU) issues as they apply to 28.8 kb/s modems. This AR looks at the switch-DLC networking architecture effects of two of the currently predominant switching systems (used by the BCCs) and two typical DLC systems with 28.8 kb/s modems.

Two of the three commonly used switching systems (identified as switches "S" and "T") were analyzed with the Lucent SLC® 96[2] DLC system and LUs, the predominent older (1970s) generation DLC, as well as a second DLC system and LUs typifying current trends in DLC architecture (referred to as system "M"). Both universal DLC (UDLC) and integrated DLC (IDLC) testing configurations were examined. Three types of 28.8 kb/s modems, designated types "X", "Y", and "Z", were used in the Bellcore analysis. Gross results for this particular analysis may be extrapolated to other models of modems. Table 1-1 illustrates the various combinations of modems, switching systems and access systems utilized for this report.

Two standard files defined in TIA/EIA TSB-38 *Test Procedure for Evaluation of 2-Wire 4-Kilohertz Voiceband Duplex Modems* were transferred over the respective DLC systems from COT to RT and vice-versa. Five transfers of each file were conducted in each direction; the average and range of the throughput measurements are provided in Appendix A. The connection rates for each of the calls were also recorded.

This analysis was limited to the configurations noted in Section 1.2 of this report. Standards for the telephone network, including DLC systems, do not include specifications for 28.8 kb/s V.34 modem performance. Conforming to the requirements in TR-57, TR-08 and/or GR-303 does not guarantee 28.8 kb/s operation. It should also be noted that the ITU V.34 Recommendation specifies modem connections at baud rates of **up to** 28.8 kb/s, implicitly stating that 28.8 kb/s connections may not always be attainable.

[1] DLC refers to any access system using m-law PCM as the encoding technique. This includes, but is not limited to, digital loop carrier systems, hybrid fiber-coax systems, fiber-in-the-loop systems, and radio-based systems.

[2] SLC is a registered trademark of Lucent Technologies.

Table 1-1. Modems, Systems, and Line Units Used

Test #	Modem	Switching and Access Systems	Line Unit
1	"X"	SLC® 96 RT/Switch "S" IDLC to IDLC	WP20D
	"X"	SLC® 96 RT/UDLC to IDLC	WP20D
	"X"	SLC® 96 RT/UDLC to UDLC	WP20D
2	"X"	SLC® 96 RT/UDLC to UDLC	WP20D
	"Y"	SLC® 96 RT/UDLC to UDLC	WP20D
	"Z"	SLC® 96 RT/UDLC to UDLC	WP20D
3	"X"	System "M" RT/Switch "S" IDLC to IDLC	POTS RT Type #1
	"X"	System "M" RT/Switch "S" IDLC to IDLC	POTS RT Type #2
	"X"	System "M" RT/Switch "S" IDLC to IDLC	UVG RT
4	"Y"	System "M" RT/Switch "T" IDLC to IDLC	POTS RT Type #1
	"Y"	System "M" RT/Switch "T" IDLC to IDLC	POTS RT Type #2
	"Y"	System "M" RT/Switch "T" IDLC to IDLC	UVG RT
5	"Z"	System "M" RT/Switch "S" IDLC to IDLC	POTS RT Type #1
	"Z"	System "M" RT/Switch "S" IDLC to IDLC	POTS RT Type #2
	"Z"	System "M" RT/Switch "S" IDLC to IDLC	UVG RT

1.1.1 Product Description

SLC® 96 System

The Lucent SLC® 96 system, which was introduced in 1979, is a DLC system that provides service on up to 96 subscriber lines over three (Mode II) to five (Mode I) DS1 lines between a Remote Terminal (RT) and a Central Office Terminal (COT). At the 1984 divestiture of the Bell System, there were more than 10 million lines in the field. Greater than 90% of all DLC supported by the BCCs were SLC® 96 systems at that time. SLC® 96 systems are first generation DCL technology with a per shelf CODEC shared by 24 lines and fixed timeslot assignment (no cross-connects).

WP10C & WP10D COT POTS LUs

The WP10C and WP10D COT line units (LUs) are designed for 2-wire, loop-start (LS) POTS service. The dual POTS COT current sink LUs were paired with WP20D LUs in the SLC® 96 RT for the analysis.

WP20D RT POTS LU

The WP20D LU is designed for 2-wire, LS POTS service. It is a dual channel current source unit.

System "M"

System "M" is representative of current DLC technology. It is a typical emerging access systems with some of the following characteristics:

- Operation over SONET fiber optic link
- Supports TR-57 UDLC configuration
- Supports TR-08 IDLC configuration
- Supports TR-303 IDLC configuration
- Supports integrated network access
- Full service capability for locally-switched services
- Full time slot interchange capability
- Per-line CODEC

POTS Type #1 LU

The first type of POTS LU is a new generation LU used at the System "M" RT to provide single party message telephone service. It contains four independent single-party circuits. This RT LU provides service over a range of 0 to 1500 ohms including the resistance of the station equipment.

POTS Type #2 LU

The second type of POTS LU is an older generation LU used at the System "M" RT to provide single party message telephone service. It contains two independent single-party circuits. This RT LU provides service over a range of 0 to 1500 ohms including the resistance of the station equipment.

UVG LU

The UVG LU is an older generation LU used at the System "M" RT to provide typical universal voice grade services. This UVG LU provides only one circuit per line unit.

1.1.2 System Configuration & Test Environment

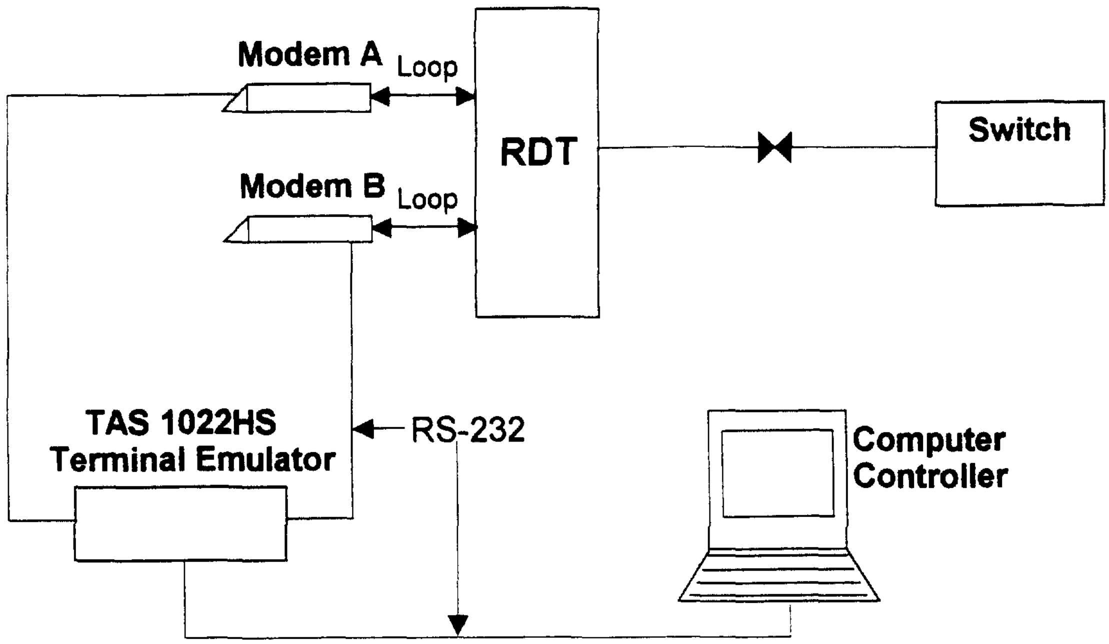

Figure 1-1. Modem Test Configuration - IDLC Setup

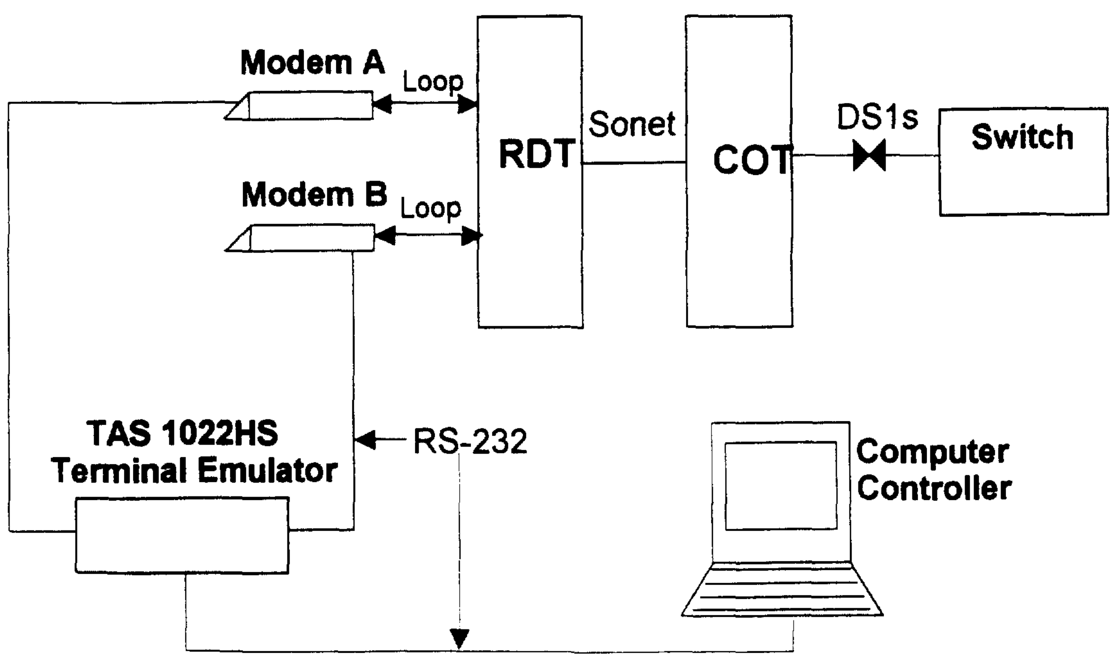

Figure 1-2. Modem Test Configuration - UDLC Setup

The test setups detailed in Table 1-1 involved a System "M" COT and RT and a SLC® 96 COT and RT (with appropriate POTS and UVG LUs). For tests involving the System "M" COT and RT, the access systems were co-located and installed as integrated DLC configurations in the Bellcore DLC Laboratory in Morristown, NJ. For tests involving the SLC® 96 system, the access systems were installed as integrated and/or universal DLC configurations with the COT located at the Bellcore facility in Red Bank, NJ (for universal testing) and the RT located at the Bellcore facility in Morristown, NJ. Bellcore corporate network MUXs were used for the DS1 connections between Morristown and Red Bank. In all cases, each system was externally timed from a composite Stratum 1 level Cesium clock source.

1.1.3 Test Plan & Test Procedure

Testing was guided by the TIA/EIA Telecommunications Systems Bulletin - TSB-38 *Test Procedure for Evaluation of 2-Wire 4-Kilohertz Voiceband Duplex Modems*, December 1994. File based transfer tests were used. The file based transfer with compression test shows how well the modem will perform in typical asynchronous applications.

The goal of this analysis was to measure throughput performance for a variety of DLC channels. Two standard files defined in TIA/EIA TSB-38 were transferred over the respective DLC systems from COT to RT and vice-versa. The two files chosen were intended to represent a broad range of user data. The two files chosen were the Random pattern file and the Text file. The Random file is taken from a 64 bit random number generator, and its characteristics are typical for files compressed with Lempel-Ziv algorithms, e.g., the PC-DOS PKZIP utility. The Text file is taken from a WordPerfect word-processing file. Additional information on the standard files is provided in Appendix A. Five transfers of each file were conducted in each direction; the average and range of the throughput measurements are provided in Appendix A. The connection rates for each of the calls were also recorded. File compression and error correction were enabled. All of the file transfers for each system were conducted during the same connection.

Many applications, such as file transfer, involve the transmission of data in a single direction. These applications are represented by one-way throughput tests. Some other applications, such as LAN bridging and applications sharing, require that significant amount of data be transferred in both directions at the same time. Two-way throughput tests are good indications of performance for these uses.

A Telecom Analysis Systems TAS 1022HS Modem Tester was used to control the modems, transmit/receive data, and measure throughput rates. The DTE port rate on the TAS 1022HS Modem Tester was set to 115.2 kb/s because the 28.8 modems perform 4:1 compression. Procomm PLUS[3] for Windows was used to communicate with the TAS Modem Tester. A script file, written in Procomm's Windows Aspect Script (WAS) language was used to transfer the files in succession and log results.

Before any tests were run on the DLC systems, the modems used for the analysis were characterized with respect to their performance over copper. The throughput and connect rates were measured with the modems transmitting over 0 loop (i.e., "back-to-back"). The transmit level of the modems was also varied; the modems have a dip switch that enabled a 0 dBm or -10 dBm

[3]Procomm PLUS is a registered trademark of Datastorm Technologies, Inc.

transmit level. In all combinations of test cases, the modem connect rate was 28.8 kb/s and the throughput rate was nearly identical. The throughput rate for the Random file was about 3360 characters per second (cps) in both the COT-to-RT and RT-to-COT directions, and the throughput rate for the Text file was 7860 cps in the COT-to-RT direction and 8050 in the RT-to-COT direction. The difference in the throughput rates for the Text file in each direction was due to the modem characteristics. On the asynchronous RS-232 interface side, one character is represented by 10 bits (i.e., 8 data bits + 1 start bit + 1 stop bit). On the line side of the modem, groups of characters (with each character represented by 8 bits, after the modem removes the start and stop bits) are sent in large blocks of data, and as a result, the throughput of incompressible data (i.e., the Random file) is able to exceed 28,800 bits/s by almost 20%.

When the tests were being run on the individual carrier systems, once a connection was made, the file transfers were started. All dropped connections and errored transmissions were noted, but once a successful run was obtained, the results were recorded and testing began on the next LU type. Connect reliability for all test cases varied between 97% and 100%.

1.2 Analysis Results and Observations

Appendix A contains the results of the analysis, which will be discussed here on a case-by-case basis.

Test Case #1

Constant Parameters: Modem "X", SLC® 96 DLC System, WP20D LU
Variable Parameters: IDLC to IDLC, UDLC to IDLC, UDLC to UDLC

For IDLC to IDLC: With the exception of one instance, the SLC® 96 system connect rate was 26.4 kb/s in both the transmit and receive directions. The throughput was slightly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2910 cps to 3140 cps. For text files, the average range was from 7130 cps to 7860 cps. The throughput for simultaneous text file transfers from modem B to modem A and modem A to modem B (tba|rba) was consistently lower than the other transmission conditions. Similar (although less pronounced) results were noticed for random file transfers. The throughput measurements varied by up to 10% (depicted in the Appendix A graphs by the long vertical lines).

For UDLC to IDLC: The SLC® 96 system connect rate was 24.0 kb/s in both the transmit and receive directions. As a result, the throughput was degraded from both the back-to-back configuration and the IDLC to IDLC configuration. For random files, the average throughput was approximately constant at 2840 cps. For text files, the average range was from 6840 cps to 6890 cps. There was no noticeable deviation in throughput for any particular transmission/receive modem transmission conditions.

For UDLC to UDLC: The SLC® 96 system connect rate was 21.6 kb/s in both the transmit and receive directions. As a result, the throughput was *significantly* degraded from the back-to-back configuration and noticeably degraded from both the IDLC to IDLC configuration and the UDLC to IDLC configuration. For random files, the average throughput 5480 cps to 5880 cps. The throughput for text file transfers from modem B to modem A (tb|ra) was consistently higher than the other transmission conditions. Similar results were noticed for random file transfers.

Test Case #2

Constant Parameters: SLC® 96 DLC System, WP20D LU, UDLC to UDLC
Variable Parameters: Modem "X", Modem "Y", Modem "Z"

For Modem "X": The SLC® 96 system connect rate varied from 21.6 kb/s to 24.0 kb/s in the transmit direction, and varied from 19.2 kb/s to 21.6 kb/s in the receive direction. The throughput was significantly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2110 cps to 2460 cps. For text files, the average range was from 4910 cps to 5950 cps. The throughput for simultaneous text file transfers from modem B to modem A and modem A to modem B (tba|rba) was consistently the lowest of the transmit conditions. The throughput for text file transfers from modem B to modem A (tb|ra) was consistently the highest. Similar results were noticed for random file transfers. The throughput measurements varied by up to 10% (depicted in the Appendix A graphs by the long vertical lines).

For Modem "Y": The SLC® 96 system connect rate varied from 21.6 kb/s to 24.0 kb/s in the transmit direction, and varied from 19.2 kb/s to 21.6 kb/s in the receive direction. The throughput was significantly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2190 cps to 2320 cps. For text files, the average range was from 4410 cps to 5240 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower than the single direction text file transfers (ta|rb, tb|ra). Similar (although less pronounced) results were noticed for random file transfers. The throughput measurements varied by up to 12% (depicted in the Appendix A graphs by the long vertical lines). Overall, the performance of Modem "B" was observed to be slightly worse than that of Modem "A".

For Modem "Z": The SLC® 96 system connect rate was 24.0 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2740 cps to 2820 cps. For text files, the average range was from 6480 cps to 6780 cps. The throughput was relatively consistent for all transmission and receive conditions. Overall, the performance of Modem "C" was observed to be significantly better than the of either Modem "B" or Modem "A". In the UDLC to UDLC configuration, however, neither connect rates nor throughput approached the levels obtained in an IDLC to IDLC configuration.

Test Case #3

Constant Parameters: Modem "X", DLC System "M", Switch "S", IDLC to IDLC
Variable Parameters: POTS Type #1 LU, POTS Type #2 LU, UVG LU

For POTS Type #1 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was slightly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2910 cps to 3380 cps. For text files, the average range was from 7340 cps to 7840 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower than the other transmission conditions. The throughput for text file transfers from modem A to modem B (ta|rb) was consistently the highest. Similar results were noticed for random file transfers. The throughput measurements varied by as much as 10% (depicted in the Appendix A graphs by the long vertical lines).

For POTS Type #2 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was slightly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2900 cps to 3390 cps. For text files, the average range was from 7090 cps to 8230 cps. The throughput for text file transfers from modem A to modem B (ta|rb) was consistently the highest. Similar results were noticed for random file transfers. The throughput measurements varied by as much as 15% (depicted in the Appendix A graphs by the long vertical lines).

For UVG LU: The connect rate for System "M" was 28.8 kb/s in the transmit direction and 26.4 kb/s in the receive direction. The throughput was slightly degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2940 cps to 3230 cps. For text files, the average range was from 7200 cps to 7650 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower than the other transmission conditions. The throughput for simultaneous text file transfers from modem B to modem A and modem A to modem B (tba|rba) was consistently lower than the other transmission conditions. Similar results were noticed for random file transfers. The throughput measurements varied by as much as 10% (depicted in the Appendix A graphs by the long vertical lines).

Test Case #4

Constant Parameters: Modem "Y", DLC System "M", Switch "T", IDLC to IDLC
Variable Parameters: POTS Type #1 LU, POTS Type #2 LU, UVG LU

For POTS Type #1 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2730 cps to 3220 cps. For text files, the average range varied greatly from 4630 cps to 7490 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently much lower (more than 2000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers.

For POTS Type #2 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2590 cps to 3140 cps. For text files, the average range varied greatly from 4630 cps to 7000 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently much lower (more than 2000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers. The throughput measurements varied by as much as 12% (depicted in the Appendix A graphs by the long vertical lines).

For UVG LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2620 cps to 2950 cps. For text files, the average range varied greatly from 4630 cps to 7000 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently much lower (more than 2000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers. The throughput measurements varied by as much as 12% (depicted in the Appendix A graphs by the long vertical lines).

Test Case #5

Constant Parameters: Modem "Z", DLC System "M", Switch "S", IDLC to IDLC
Variable Parameters: POTS Type #1 LU, POTS Type #2 LU, UVG LU

For POTS Type #1 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 3220 cps to 3380 cps. For text files, the average range varied greatly from 6740 cps to 8000 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower (more than 1000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers. The throughput measurements varied by as much as 15% (depicted in the Appendix A graphs by the long vertical lines).

For POTS Type #2 LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2770 cps to 3380 cps. For text files, the average range varied greatly from 6830 cps to 7820 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower (more than 1000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers. The throughput measurements varied by as much as 15% (depicted in the Appendix A graphs by the long vertical lines).

For UVG LU: The connect rate for System "M" was 28.8 kb/s in both the transmit and receive directions. The throughput was degraded from the back-to-back configuration. For random files, the average throughput varied from approximately 2750 cps to 3370 cps. For text files, the average range varied greatly from 6450 cps to 7930 cps. The throughput for simultaneous text file transfers (tab|rab, tba|rba) was consistently lower (more than 1000 cps) than the other transmission conditions. Similar (although much less dramatic) results were noticed for random file transfers. The throughput measurements varied by as much as 30% (depicted in the Appendix A graphs by the long vertical lines).

1.3 Conclusions

The results presented in this Report indicate that the performance of different modems on DLC systems varies widely. When used on the same system, as in Test Case #2, Modems "X", "Y", and "Z" displayed markedly different performance, with different connect speeds and throughput. It was also demonstrated (in Test Cases #4 and #5) that two of the modems ("Y" and "Z") displayed an extreme throughput drop-off of text files when simultaneous transmission was taking place in both the forward and reverse directions. This problem was not apparent in tests performed on Modem "X" (Test Case #3).

This analysis investigated the differences between using modems on IDLC to IDLC systems, UDLC to IDLC systems, and UDLC to UDLC systems. Modem performance varied greatly for each, being the best for the all-IDLC systems, somewhat worse for mixed IDLC/UDLC systems, and considerably worse for all-UDLC systems. Modem performance for all-IDLC systems was often 150% of that of all-UDLC systems. **This is demonstrable evidence of a functional advantage gained by using integrated DLC systems over universal DLC systems.**

Two of the major factors contributing to these system variations are: (1) μ-law PCM limits the signal-to-noise ratio to 37 to 38 dB at best, per encoding or decoding, and (2) Two-wire back-to-back hybrids at each encoding or decoding also lower net return loss and increase echo. Successive analog to digital (μ-law PCM) and digital to analog conversions mulitply degradation to the throughput of 28.8 kb/s modems. One PCM link typically results in a connect rate of 26.4 -28.8 kb/s. Two PCM links typically result in a connect rate of 24.0-26.4 kb/s. Three PCM links typically result in a connect rate of 16.8-21.6 kb/s. IDLC systems have fewer PCM links than mixed IDLC/UDLC system configurations, which, in turn, have fewer PCM links than UDLC system configurations. As a result, connect rates and throughput can be expected to be worst through UDLC system configurations and best through IDLC system configurations.

Other variables investigated in this study, such as varying line units and DLC systems showed some deviations, but nothing dramatic. Changing between various POTS and UVG LUs did not appreciably affect throughput or connect rates (throughput was the same to within 10-20% in all cases). Likewise, no drastic variations were seen when changing from the SLC® 96 DLC system, a system using older generation technology, to System "M", which uses modern technology. This reinforces the fact that μ-law PCM is the limiting factor for modem transmission over DLC systems, not the specific system or system technology being used.

1.4 Past and Future Work

This analysis contained follow-up information to that presented in the Reports listed in Table 1-2. It is an attempt at examining the effects of DLC and switching systems on 28.8 kb/s modem performance, in particular, the connect rate and throughput. The reports listed below provide details on performance for DLC systems and LUs from specific manufacturers.

Suggestions for additional studies regarding 28.8 kb/s modem performance include:

- Analyzing a wide range of loops (e.g., mid-range loops, loops with excessive bridged tap).
- Analyzing interoffice trunking and cross-connect systems.
- Analyzing the effect on switching systems of multiple customer lines running at rates close to 36 ccs (due to Internet/World Wide Web connections).

Table 1-2. Related Reports on Modem Interoperability

Report	Keywords from Title	Release Date
AR-2221	Interop. AT&T Switching & Access Systems with 28.8 kb/s Modems	December 1995
AR-2222	Interop. Pulsecom AUA38A and AUA58C POTS LUs for AT&T SLC® Series 5 DLC System with 28.8 kb/s Modems	January 1996
AR-2223	Interop. DSC Litespan®-2000 Access System with 28.8 kb/s Modems	January 1996
AR-2224	Interop. Ericsson Raynet® LOC™ 2 FITL System with 28.8 kb/s Modems	January 1996
AR-2225	Interop. Fujitsu FDLC Access System with 28.8 kb/s Modems	January 1996
AR-2226	Interop. R-Tec DISC*S-1 Access System with 28.8 kb/s Modems	January 1996

References

1. TIA/EIA Telecommunications System Bulletin, TSB-37A, *Telephone Network Transmission Model for Evaluating Modem Performance,* October 1994, Published by the Telecommunications Industry Association.

2. TIA/EIA Telecommunications System Bulletin, TSB-38A, *Test Procedure for Evaluation of 2-Wire 4-Kilohertz Voiceband Duplex Modems,* December 1994, Published by the Telecommunications Industry Association.

3. ITU-T Recommendation V.34, *A Modem Operating at Data Signaling Rates of up to 28,800 bit/s for use on the General Switched Telephone Network and on Leased Point-to-Point 2-wire Telephone-Type Circuits*, September 1994.

4. TR-TSY-000057, *Functional Criteria for Digital Loop Carrier Systems*, Issue 2, January 1993, Published by Bellcore.

5. TR-TSY-000008, *Digital Interface between the SLC® 96 Digital Loop Carrier System and a Local Digital Switch*, Issue 2, August 1987, Revision 1, September 1993, and Bulletin 1, October 1994, Published by Bellcore.

6. GR-303-CORE, *Integrated Digital Loop Carrier System Generic Requirements, Objects, and Interface*, Issue 1, September 1995, Published by Bellcore.

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Appendix: 28.8 kb/s Modem Throughput Test Results

A.1 Data Files Used for Throughput Tests

The data files included in TSB-38 represent the different types of data that might be transferred between modems in typical user applications. There are five different types of data files in TSB-38, and two of the five (i.e., the Text and Random files) were chosen for this analysis. The Text file is from a WordPerfect word processing file, and the Random file is taken from a 64 bit random number generator, and its characteristics are typical for files compressed with Lempel-Ziv algorithms.

The data files are provided in two forms. The segment form is a 32,768-byte file, which the DTE shall send a specific number of times one after another. The extended form is a full-length file that the DTE shall send once. The extended form files each consist of a specific number of repetitions of the segment form files.

The naming convention for a segment form file in *n*.TST when *n* is the file number. The naming convention for an extended form file is *nXmm*.TST where *n* is the file number and mm is the number of times the 32 kb segment is repeated. For example, 4X04.TST is the file 4.TST (i.e., the random file) repeated four times. Table A-1 below indicates the names of the files used along with their file sizes.

Table A-1. Throughput Test Files

Segment File Name	2.TST (Text file)	4.TST (Random file)
Repetitions	10	4
Extended File Name	2X10.TST	4X04.TST
Size (bytes)	327,680	131,072
Reference Throughput Value (per TSB-38)	8,288 cps	3,434 cps

A.2 Throughput Measurements

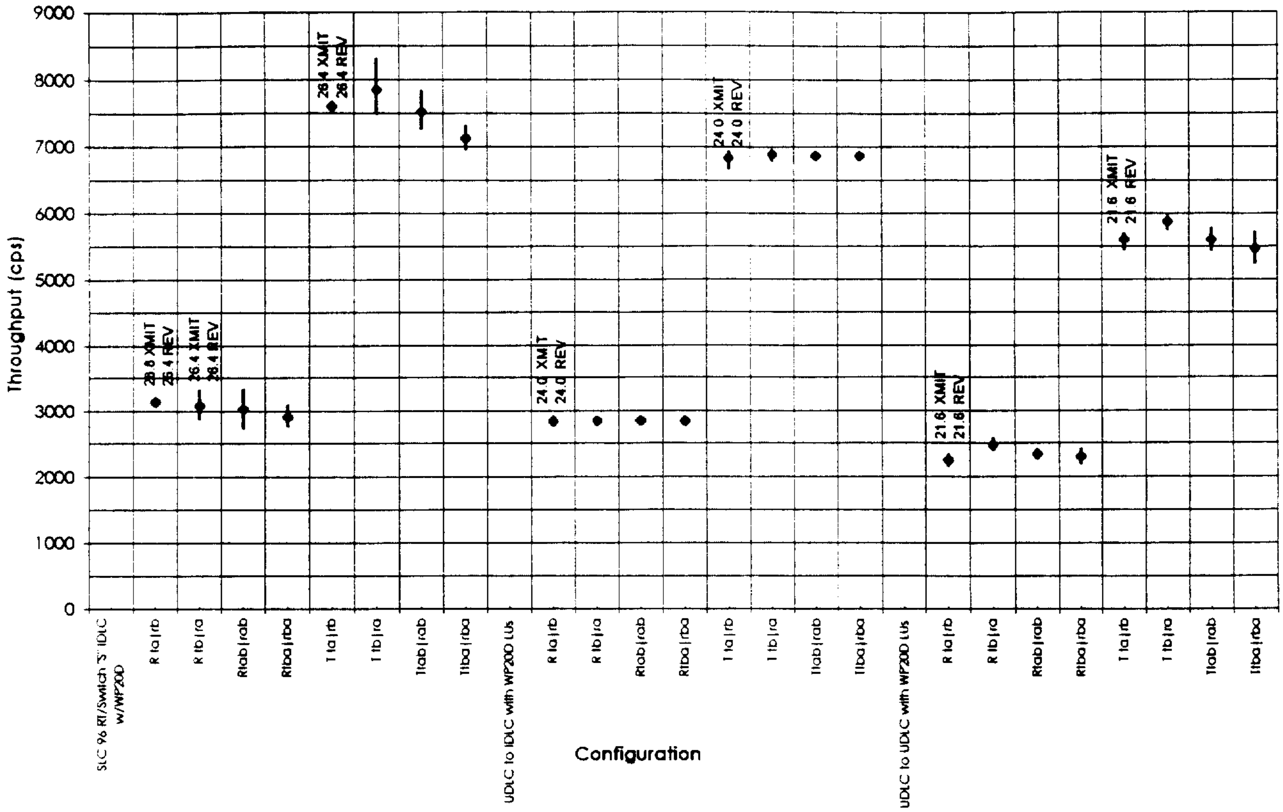
In this appendix, the data is presented in both spreadsheet and graphical representations. Procomm PLUS for Windows was used to control the TAS 1022HS Modem Tester and log the file throughput results. A Script file, written in Procomm's Windows Aspect Script (WAS) language, was used to initialize the modems, conduct the file transfers and record the results in a capture file. The Random file was transferred first from the A modem to the B modem and then from the B modem to the A modem. In the spreadsheets and graphs that follow, these transfers are referred to as R ta|rb and R tb|ra, respectively. Simultaneous transfers from the A modem to the B modem and the B modem to the A modem are referred to as R tab|rba and R tba|rab. Transfers of the Text file are referred to as T ta|rb, T tb|ra, T tab|rba, and T tba|rab. When the tests were being run on the individual carrier systems, once a connection was made, the file transfers were started. All dropped connections and errored transmissions were noted, but once a successful run was obtained, the results were recorded and testing began on the next LU type.

In order to have the modems connect through the carrier systems, an "ATO" command was sent to the originating modem, which was the B modem at the RT, and an "ATA" command was sent to the terminating (or answering) modem, which was the A modem at the COT. When tests were run through switched connections, an "AT(telephone #)" command was sent to the originating modem, in order to have it dial the other modem through the switch.

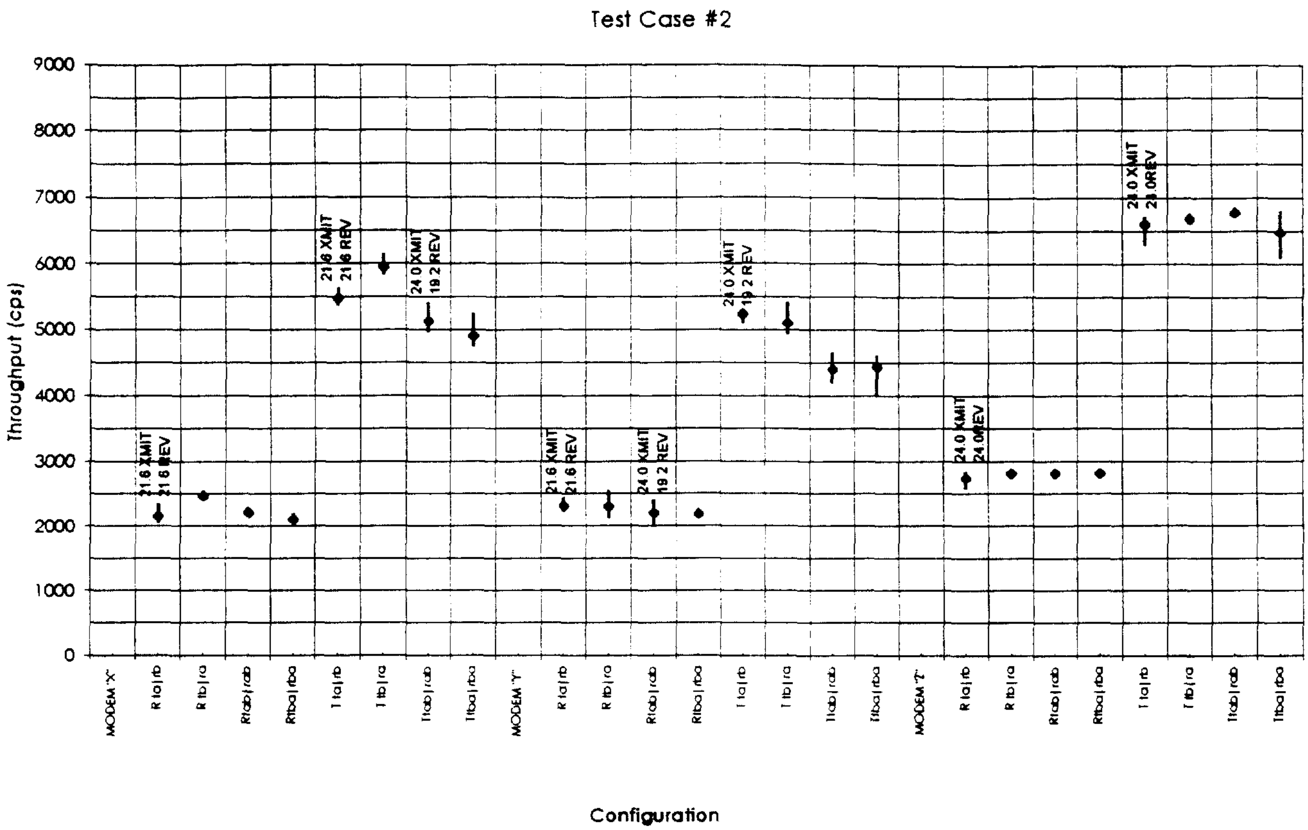
The connect rate for each connection was also recorded at the beginning of each connection and at the end of all of the file transfers. This was based on information obtained from the modem via the computer program.

A.3 Analysis Results

Test Case #1



Modem "X"				
	Average	Minimum	Maximum	Connect Rate
SLC 96 RT/Switch "S" IDLC w/WP20D				
R ta|rb	3.14E+03	3.14E+03	3.14E+03	28800/26400
R tb|ra	3.09E+03	2.89E+03	3.31E+03	28800/26400
Rtab|rab	3.03E+03	2.75E+03	3.32E+03	
Rtba|rba	2.91E+03	2.78E+03	3.08E+03	28800/26400
T ta|rb	7.60E+03	7.58E+03	7.61E+03	28800/26400
T tb|ra	7.86E+03	7.50E+03	8.30E+03	28800/26400
Ttab|rab	7.53E+03	7.28E+03	7.82E+03	
Ttba|rba	7.13E+03	6.97E+03	7.30E+03	28800/26400
UDLC to IDLC with WP20D LUs				
R ta|rb	2.84E+03	2.81E+03	2.86E+03	24000/24000
R tb|ra	2.85E+03	2.81E+03	2.86E+03	24000/24000
Rtab|rab	2.84E+03	2.84E+03	2.84E+03	
Rtba|rba	2.84E+03	2.84E+03	2.84E+03	24000/24000
T ta|rb	6.84E+03	6.69E+03	6.92E+03	24000/24000
T tb|ra	6.89E+03	6.80E+03	6.92E+03	24000/24000
Ttab|rab	6.87E+03	6.87E+03	6.87E+03	
Ttba|rba	6.87E+03	6.87E+03	6.87E+03	24000/24000
UDLC to UDLC with WP20D LUs				
R ta|rb	2.25E+03	2.17E+03	2.32E+03	21600/21600
R tb|ra	2.47E+03	2.41E+03	2.57E+03	21600/21600
Rtab|rab	2.34E+03	2.27E+03	2.39E+03	
Rtba|rba	2.31E+03	2.21E+03	2.40E+03	21600/21600
T ta|rb	5.61E+03	5.47E+03	5.69E+03	21600/21600
T tb|ra	5.88E+03	5.76E+03	5.98E+03	21600/21600
Ttab|rab	5.60E+03	5.45E+03	5.76E+03	
Ttba|rba	5.48E+03	5.25E+03	5.70E+03	21600/21600



Three Different Modems over UDLC to UDLC				
	Average	Minimum	Maximum	Connect Rate
MODEM "X"				
R ta|rb	2.15E+03	2.08E+03	2.33E+03	21600/21600
R tb|ra	2.46E+03	2.41E+03	2.53E+03	21600/21600
Rtab|rab	2.21E+03	2.17E+03	2.25E+03	
Rtba|rba	2.11E+03	2.04E+03	2.17E+03	21600/21600
T ta|rb	5.48E+03	5.39E+03	5.62E+03	21600/21600
T tb|ra	5.95E+03	5.85E+03	6.13E+03	21600/21600
Ttab|rab	5.13E+03	4.98E+03	5.39E+03	
Ttba|rba	4.91E+03	4.77E+03	5.22E+03	21600/21600
MODEM "Y"				
R ta|rb	2.32E+03	2.24E+03	2.42E+03	21600/21600
R tb|ra	2.30E+03	2.14E+03	2.53E+03	21600/21600
Rtab|rab	2.20E+03	2.01E+03	2.39E+03	
Rtba|rba	2.19E+03	2.15E+03	2.20E+03	24000/19200
T ta|rb	5.24E+03	5.12E+03	5.30E+03	24000/19200
T tb|ra	5.10E+03	4.96E+03	5.40E+03	24000/19200
Ttab|rab	4.41E+03	4.22E+03	4.64E+03	
Ttba|rba	4.44E+03	4.04E+03	4.60E+03	24000/19200
MODEM "Z"				
R ta|rb	2.74E+03	2.60E+03	2.82E+03	24000/24000
R tb|ra	2.81E+03	2.81E+03	2.82E+03	24000/24000
Rtab|rab	2.82E+03	2.82E+03	2.82E+03	
Rtba|rba	2.81E+03	2.81E+03	2.82E+03	24000/24000
T ta|rb	6.61E+03	6.31E+03	6.69E+03	24000/24000
T tb|ra	6.69E+03	6.67E+03	6.70E+03	24000/24000
Ttab|rab	6.78E+03	6.77E+03	6.78E+03	
Ttba|rba	6.48E+03	6.11E+03	6.79E+03	24000/24000